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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Confirmation No.:	4154
Application No.:	10/077,391
Invention:	CASTING STEEL STRIP
Applicant:	Nikolovski et al.
Filed:	February 15, 2002
Attorney Docket:	29385-69914
Examiner:	Tran, Len

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I hereby certify that this correspondence is being facsimile transmitted to the United States Patent and Trademark Office (Division), fax number (703) 746-7296.

on July 22, 2003

(Signature)

Eric W. Beard

(Printed Name)

SUPPLEMENTAL RESPONSE

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

On July 14, 2003, applicant submitted a letter response to the Office Action dated March 13, 2003. Applicants now submit as further evidential support, translations of JP 08294751 and JP 58-29547.

As the translation shows, JP '751 is further evidence of **non**-obviousness of the presently claimed subject matter. Shot blasting is utilized to form an inner layer 9 to provide good heat transmission properties between the outer layer 13 and the inner layer 9. Translation at 5, ll. 15-17. The material and method of forming the outer layer 13 is not specified, but the outer layer 13 can be readily formed by Ni-plating or Cr-plating or Ni + Cr-plating the inner layer 9 and polishing the surface after the completion of the plating. *Id* at ll. 4-8. In any case "the outer surface of the outer layer 13 is **finished smoothly**, and the degree of smoothness is preferably for example, the same as the level of smoothness of a normal cold rolling roll". *Id* at ll. 8-10 (emphasis added).

JP 757's teaching is directly contrary to the teachings of claims 14 and 15 of the presently claimed subject matter, which direct utilizing grip blasting to form the outer casting surface of the casting rolls. Moreover, JP '751's teaching is directly contrary to claims 11-19, which specify that the pair of casting rolls of a roll caster have casting surfaces being textured by a random pattern of discrete projections. See claim 9.

JP '547 is more remote prior art. It is directed to the inner mould of a continuous slab casting machine. Moreover, the inner surface of the mould is formed of a **cobalt-**molybdenum-copper alloy layer. There is no disclosure or suggestion of utilizing a nickel chromium molybdenum alloy layer to form the mould surface. Again, the teachings are directly contrary to claims 20 and 21 against which JP '547 is cited.

Applicant respectfully submits that claims 1-31 are in condition for allowance and should be allowed. If the Examiner has any further questions after reviewing the references in view of the above comments and the comments in the letter of July 14, 2003, applicant respectfully requests that the Examiner arrange an interview with applicants counsel, Arland T. Stein, Esq. (317-231-7390).

Respectfully,

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54 Title of Invention: Mould for Continuous Casting Machine

21 Patent Application Number: 56-126016
22 Date of Application: 13th August 1981

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SPECIFICATIONS

1. Title of the Invention

Mould for Continuous Casting Machine

2. Claims

A mould for a continuous casting machine, such mould characterized in that a Ni-plated layer is formed upon the inner surface of the mould, and in that a layer formed of a Co-Mo-Cr alloy consisting of 45 wt% to 65 wt% Co, 20 wt% to 40 wt% Mo, and with the balance being Cr of from 50 μ to 700 μ in thickness is formed over the Ni-plated layer

3. Detailed Description of the Invention

This invention relates to a mould for a continuous casting machine, and more particularly, to a continuous casting machine mould that exhibits excellent resistance to wear and excellent resistance to seizure.

Copper or copper alloy is employed in order to increase the cooling effect as the matrix for moulds for continuous casting machines. However, all such metals lose their hardness and strength under high temperature conditions, and hence, when employed in their pure state, the wear against the surface that is in contact with the cast slab (hereinafter referred to simply as the 'inner surface'), and such moulds cannot be employed for long periods of time. Moreover, the copper permeates the surface of the cast slab and is the cause of surface defects in the cast slab known as star cracking.

Consequently, the inner surfaces of casting moulds are commonly coated with materials other than copper or copper alloys in order to overcome these problems. The most commonly employed coating material and method of applying the coating are Ni or Cr applied by electroplating, while apart from this, some use is also made of eutectic plating as a special plating method, in which Ni-P or mixtures of various pluralities of metals, metal oxides and oxides are employed. Moreover, other methods of coating apart from plating, such as blasting, principally with Ni, and also spraying with Mo alloys, Fe alloys and WC-Co and so forth (JP49-24837) are known.

However, in recent years the size of the cast slab has tended to increase and the casting velocity has tended to rise, and hence the casting conditions have become more demanding than was hitherto the case, with the result that the coating methods described above no longer necessarily provide satisfactory results. For example, in the case of a conventional curved continuous slab casting machine, a coating of approximately 3 mm thick of Ni would be applied to the inner surface of the casting mould, but the service life of the coating would not exceed 150 to 200 charges at a casting velocity of from 1.2 m/min to 1.6 m/min.

In order to overcome these problems, the present invention is characterized in that in that a Ni-plated layer is formed upon the inner surface of the mould, and in that a layer formed of a Co-Mo-Cr alloy consisting of 45 wt% to 65 wt% Co, 20 wt% to 40 wt% Mo, and with the balance being Cr of from 50 μ to 700 μ in thickness is formed over the Ni-plated layer.

The invention is now described in greater detail.

The interior of the casting mould is coated with a plated layer of from 30 μ to 200 μ in thickness, whereupon a layer formed of a Co-Mo-Cr alloy consisting of 45 wt% to 65 wt% Co, 20 wt% to 40 wt% Mo, and with the balance being Cr of from

50 μ to 700 μ in thickness is formed over the plated layer. This coating is formed by spraying.

In the present invention, the application first of a Ni-plated layer to the inner surface of the casting mould, followed by the spraying of a Co-Mo-Cr alloy layer to form a coating is intended to enhance adhesion, and the thickness of the Ni-plated layer should be from 30 μ to 200μ in order to achieve that objective. If the thickness of the Ni-plated layer is less than 30 μ, the shot blasting that is performed as a pretreatment to the spraying abrades the Ni-plated layer, whereas, if the thickness of the Ni-plated layer exceeds 200 μ, the temperature gradient in the Ni-plated layer increases, and the thermal stress generated thereby leads to problems of stripping of the Ni-plated layer.

Next, the Co-Mo-Cr alloy layer is formed by spraying upon the Ni-plated layer. In the environment in which the Co-Mo-Cr alloy is used, this generates a cobalt molybdate salt ($CoMoO_4$), and this alloy layer exhibits excellent resistance to wear and excellent resistance to seizure. Consequently, the range of the Co and Mo constituents contained is of particular importance, because the range must be such as to lead to the formation of $CoMoO_4$ under the temperature régime achieved inside the casting mould during casting. The inventors of the present invention embedded a plurality of thermocouples in a casting mould and measured the temperature of the casting mould during casting, and tested many different ranges of the Co and Mo constituents. As a result, it was found that from 45 wt% to 65 wt% of Co and from 20 wt% to 40 wt% of Mo was the optimum range for these constituents. However, the balance of Cr should be added in order to further enhance the high temperature hardness of the alloy layer. The thickness of the alloy layer is stipulated to be from 50 μ to 700 μ because, if the thickness is less than 50 μ, the layer is too thin and the effect of the alloy layer is not achieved, whereas, if the thickness exceeds 700 μ, the thermal stress within the alloy layer increases, as was described for the Ni-plated layer, adhesion becomes unsatisfactory and the objective is not achieved.

Next, the effects of the employment of the casting mould envisaged by the present invention as the mould for a curved continuous slab casting machine are described.

A Ni-plated layer of 50 μ in thickness is formed upon the inner surface of a copper alloy casting mould substrate, and a Co-Mo-Cr alloy layer consisting of 55 wt% Co, 35 wt% Mo and 10 wt% Cr and of 150 μ in thickness is formed by plasma spray upon the Ni-plated layer. Next, Al-killed steel slabs 220 mm thick, and from 950 mm to 1600 mm wide are cast by means of this casting mould at a casting velocity of from 1.2 m/min to 1.6 m/min, and the inner surface of the casting mould is examined for the development of star cracking.

Figure 1 shows the results combined with the results of the use of a conventional casting mould in which the inner layer was Cr-plated, and a casting mould in which the inner layer was Ni-plated.

It is evident from Figure 1 that the casting mould envisaged by the present invention provided a service life of several times those of the casting moulds of the prior art.

Naturally, the casting mould envisaged by the present invention fully exhibits these functions both when employed as the casting mould in vertical type continuous casting machines and in horizontal type continuous casting machines.

In the present invention as described above, Ni-plating is applied to the inner surface of the casting mould, and furthermore a Co-Mo-Cr alloy layer is formed thereupon, whereby the advantageous effect of a greatly extended service life in comparison with casting moulds of the prior art is achieved.

4. Simplified description of the drawing

Figure 1 is a drawing showing the correlation between the number of charges and the star cracking formation index.

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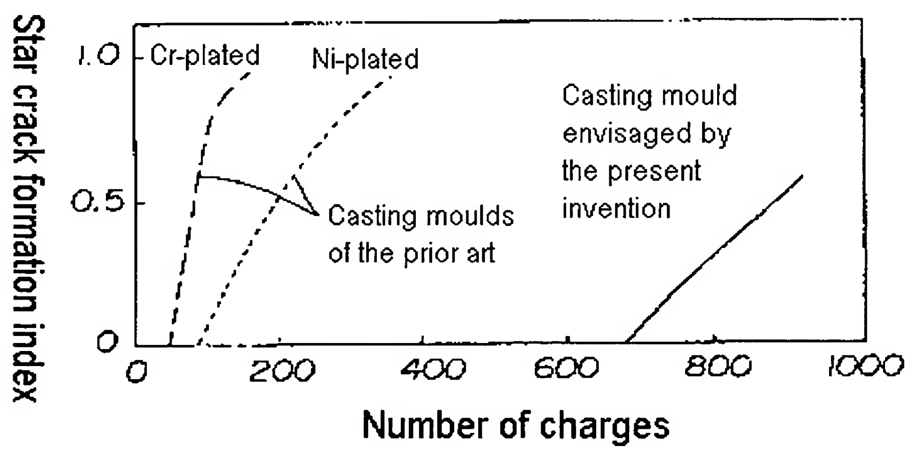

Figure 1

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22 Application date: 25th April 1995

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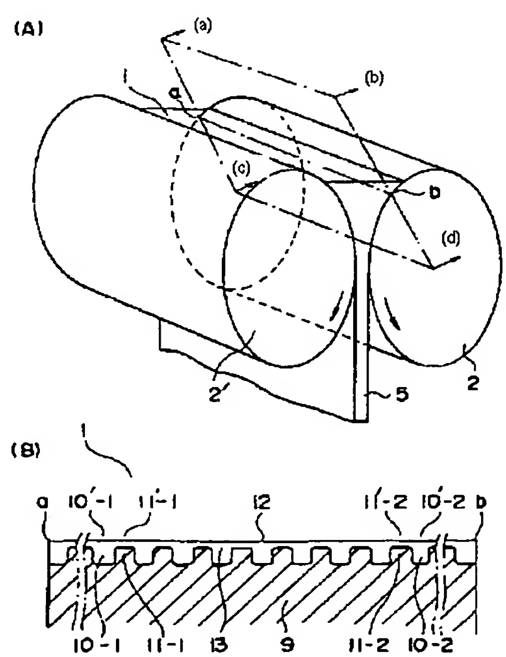
54 Title of the Invention

Casting Drums for Twin Drum Type Continuous Casting Machine



57 Abstract

Objective To provide casting drums for a twin drum type continuous casting machine, such drums enabling the manufacture of smoothly thin cast strip while preventing the formation of cracking

Constitution The surfaces of the casting drums consist of two layers, an inner layer and an outer layer, with fine recesses and protrusions being formed upon the outer surface of the copper inner layer which is covered with an outer layer of a metal other than copper, the

outer surface of the outer layer being finished smoothly. Otherwise, heat insulating material is disposed in the recesses of the copper inner layer, which is covered with a metal outer layer, the outer surface of the outer layer being finished smoothly. Otherwise, recesses and protrusions are not formed upon the outer surface of the copper inner layer, and the copper inner layer is covered with an outer layer consisting of a metal in the interior of which fine heat insulating material has been uniformly dispersed, the outer surface of the outer layer being finished smoothly.

Claims

Claim 1 Casting drums for a twin drum type continuous casting machine, such drums characterized by possessing on the surface layer an inner layer consisting of copper and that possesses uniform fine recesses and protrusions on the outer surface thereof, and an outer layer consisting of a metal other than copper that covers the inner layer upon the outer surface of the inner layer, the surface of the outer layer being finished smoothly and forming the surface of the casting drum

Claim 2 Casting drums for a twin drum type continuous casting machine, such drums characterized by possessing on the surface layer an inner layer consisting of copper and that possesses uniform fine recesses and protrusions on the outer surface thereof, and heat insulating material that is disposed in the recesses of the inner layer, and an outer layer consisting of a metal other than copper that covers the inner layer and the heat insulating material and so forth upon the outer surface of the inner layer, the surface of the outer layer being finished smoothly and forming the outer surface of the casting drum

Claim 3 Casting drums for a twin drum type continuous casting machine, such drums characterized by possessing on the surface layer an inner layer consisting of copper and an outer layer upon the outer surface of the inner layer so formed as to cover the inner layer, such outer layer consisting of metal in which fine heat insulating material is disposed in the interior thereof, the surface of the outer layer being finished smoothly and forming the surface of the casting drum

Claim 4 Casting drums for a twin drum type continuous casting machine as in Claim 2, such drums further characterized in that the heat insulating material that is disposed in the recesses of the inner layer is air holes that are formed in the said recesses of the inner layer

Claim 5 Casting drums for a twin drum type continuous casting machine as in Claim 3, such drums further characterized in that the metal in which heat insulating material is uniformly disposed is metal in which air holes are uniformly disposed

Detailed description of the invention

Relevant area of industry

[0001] This invention relates to casting drums for a twin drum type continuous casting machine for the manufacture of thin strip slab.

Prior art

[0002] Figure 4 is an explanatory drawing of a twin drum type continuous casting machine. Two horizontal casting drums **2, 2′** are disposed at the same height, parallel and adjacent to each other, each rotating in the directions of the arrows **6, 6′**. Side weirs **3, 3′** are disposed at the two extremities in the axial direction of the casting drums **2, 2′** and are attached to **2, 2′**. The two casting drums **2, 2′** possess copper substrates and are of the internally water cooled type. The molten metal **1** is poured continuously into the upper space (reservoir) that is formed by the two casting drums **2, 2′** and the side weirs **3, 3′**. The molten metal **1** that is poured is cooled by the casting drums **2, 2′**, and forms solidified shells **4, 4′** on the surfaces of **2, 2′**. These solidified shells **4** and **4′** are unified at the minimum gap between the drums **7** forming thin strip slab **5** which is withdrawn.

[0003] Such twin drum type continuous casting machine is capable of producing thin strip slab with a strip gauge of not more than 3 mm and a strip width of not less than 1000 mm, and because such thin strip slab is sufficiently thin, it can be used as is without any subsequent complex treatment, or alternatively, it may be converted into strip by means of light rolling in subsequent treatment.

[0004] JP2-165849 revealed a casting drum that was provided with on the surface thereof a plurality of grooves from 0.05 mm to 0.20 mm wide and from 0.05 mm to 0.15 mm deep. The inventors of the present invention have discovered that cracking in thin strip slab can be reduced by employing casting drums that possess on the surface thereof a plurality of recesses and protrusions. However, thin strip slab that is manufactured by means of casting drums that possess on the surfaces thereof a plurality of recesses and protrusions possess a plurality of recesses and protrusions corresponding to the recesses and protrusions of the casting drums.

[0005] As previously stated, thin strip slab from a twin drum type continuous casting machine is desirable because it can be employed without further treatment or it can be lightly rolled. However, thin strip slab that possesses on the surface thereof a plurality of recesses and protrusions is limited in its applications because it is not smoothly, or alternatively, light rolling leaves behind on the surface of the strip the marks of the recesses and protrusions, thus diminishing the visual appeal of the strip.

[0006] JP 6-67450 revealed a mould for continuous casting, such mould being formed with a plurality of layers of refractory material upon the mould movable surface. It was revealed that the first layer of refractory material was formed of for example TiN, TiC, AlN, or ZrN, and that the second layer was formed of for example ZrO_2, Al_2O_3, spinel or SiO_2.

[0007] In Figure 4, the solidified shells **4** are generated at the part **8** at which contact is initiated with the melt and grow to the thickness (t/2) at the minimum interval part **7**. This growth takes place through the cooling by the casting drums **2**. The growth time of the solidified shell **4** from **8** to **7** is short in order to cause the casting drums to revolve at high velocity in the twin drum type continuous casting machine. Internally water-cooled type casting drums with high cooling capacity in which copper forms the substrate are employed in the twin drum type continuous casting machine in order to cause the growth to thickness (t/2) within a short period of time.

[0008] When the plurality of refractory layers envisaged by JP6-67450 is formed on such casting drums **2** revolving at high speed, the cooling capacity of the casting drums is reduced because the heat propagation characteristics of the refractory layer are poorer than those of copper and solidified shells of thickness (t/2) cannot be formed. Consequently, velocity of rotation of the casting drums **2** is reduced, the volume of production of thin strip slab **5** per hour is reduced, and the production capacity of the continuous casting machine is diminished.

Problems addressed by the present invention

[0009] The objective of the present invention is to provide casting drums for a twin drum type continuous casting machine that is able to manufacture thin strip slab with high production efficiency, without surface irregularities and preventing the development of cracking in the thin strip slab.

Means employed in order to overcome these problems, and action

[0010] Figure 1 is a schematic explanatory drawing of the surface layer of the casting drums of the first invention of the inventors, Figure 1 (A) being an explanatory drawing of the locations shown, and Figure 1 (B) being a schematic explanatory drawing of the surface layer of the casting drums **2** along the cross sections indicated by arrows (a), (b), (c) and (d).

[0011] The first invention of the inventors is characterized by possessing on the surface layer in Figure 1 an inner layer **9** consisting of copper which possesses on its outer surface fine uniform recesses **10 (10-1, …, 10-2)** and protrusions **11 (11-1, …, 11-2)**, and on the outer surface of the inner layer **9** an outer layer **13** consisting of a metal other than copper that is so formed as to cover the inner layer **9**, the outer surface **12** of the outer layer **13** being finished smoothly and forming the outer surface of the casting drums **2**, these being the casting drums of a twin drum type continuous casting machine.

[0012] The shape and size of the fine recesses **10** and protrusions **11** are not specified, but for example, when shot blasting is performed on the outer surface of a copper drum, it is possible to form an inner layer **9** that possesses fine uniform recesses and protrusions of from 50 μm to 200 μm in height. The material and method of forming the outer layer **13** are not specified, but the outer surface **13** can be readily formed by Ni-plating or Cr-plating or Ni+Cr-plating the inner layer **9** and polishing the surface after the completion of plating. The outer surface of the outer layer **13** is finished smoothly, and the degree of smoothness is preferably for example the same as the level of smoothness of a normal cold rolling roll.

[0013] In Figure 1 (B), the Ni or Cr that forms the outer layer **13** transmits less heat than does Cu. The inner layer **9** is covered by the outer layer **13** that transmits less heat, but the projections **11 (11-1, 11-2)** on the inner layer **9** have good heat transmission properties because the outer layer **13** is thin, but the recesses **10 (10-1, 10-2)** on the inner layer **9** have poor heat transmission properties because the outer layer **13** is thick. Thus, within the melt **1** that is in contact with the casting drums, the melt **11′ (11-1′, 11-2′)** that faces the projections **11 (11-1, 11-2)** is rapidly cooled by the cooling drums and the progress of solidification is rapid. On the other hand, the melt **10′ (10-1′, 10-2′)** that faces the recesses **10 (10-1, 10-2)** is slowly cooled by the cooling drums and the progress of solidification is slow.

[0014] Thus, when the melt **1** comes into contact with the casting drums envisaged by the present invention, a uniformly distributed melt is formed consisting of a fine portion **11′ (11-1′, 11-2′)** in which solidification proceeds rapidly and a fine portion **10′ (10-1′, 10-2′)** in which solidification proceeds slowly.

[0015] The sizes and distribution of these fine portions can be controlled by selecting as desired the size of the recesses and protrusions that are provided on the outer surface of the inner layer **9**. Moreover, it is also possible to control as desired the extent of the difference in the progress of solidification between **10′-1** and **11′-1** through the selection of the thickness of the outer layer **13** and the type of metal of the outer layer **13**.

[0016] In Figure 1 (A), the melt **1** in the reservoir is a mixture of low temperature melt that was poured first and high temperature melt that has recently been poured, but because the mixing of the melt is not complete, the melt **1** in the reservoir is segregated into strata consisting of a low temperature portion and a high temperature portion.

[0017] When casting drums that have not received any special treatment are employed, if in Figure 1 (A) for example the low temperature melt stratum may be segregated around (a), and the high temperature melt stratum may be segregated around (b), in Figure 1 (B) **10′-1** and **11′-1** around (a) are both low

temperature, and therefore solidification proceeds rapidly, while **10′-2** and **11′-2** around (b) are both high temperature, and therefore solidification proceeds slowly. The inventors of the present invention have discovered that, when a zone in which the progress of solidification is rapid and a zone in which the progress of solidification is slow are formed, cracking readily develops in the cast slab **5**.

[0018] When the casting drums envisaged by the present invention are employed the distribution of temperatures in the melt can be so arranged that for example **11′-1** has the lowest temperature, followed by **11′-2**, followed by **10′-1**, followed by **10′-2**. Solidification also proceeds in that sequence. For that reason, solidification proceeds virtually uniformly around both (a) and (b), and it is possible to prevent the formation of zones in which solidification proceeds rapidly and zones in which solidification proceeds slowly.

[0019] The outer surface **12** of the outer layer **13** envisaged by the present invention is finished for example to the same level of smoothness as for a normal cold rolling roll. Consequently, the surface of the thin strip slab can be as smooth as the surface as cold rolled material. This overcomes the problems in use that were hitherto caused by the recesses and protrusions in the thin strip slab. Moreover, the Ni or Cr and the like that are employed as the metals for the outer layer **13** envisaged by the present invention, being metals, transmit considerably more heat than does the refractory layer envisaged by JP6-67450. Hence there is no need to reduce the velocity of rotation of the casting drums **2**, and it is possible to operate with as high a level of efficiency as hitherto.

[0020] Figure 2 is a schematic explanatory drawing of the surface of the casting drums of the second invention envisaged by the inventors, being a drawing of the same members as in Figure 1 (B). The casting drum in Figure 2 possesses on the surface thereof an inner layer **9** consisting of copper that possesses on the outer surface thereof uniform fine recesses **10** and protrusions **11**, and heat insulating material **14** that is disposed in the recesses **10** of the outer surface of the inner layer, and an outer layer **15** consisting of metal and that is so formed as to cover the outer surface of the said inner layer **9** and the heat insulating material **14**, the outer surface of such outer layer **15** being finished smoothly and forming the outer surface of the casting drum **2**, and forming a casting drum of a twin drum type continuous casting machine.

[0021] The inner layer **9** in Figure 2 may be formed in the same way as for the inner layer **9** in Figure 1. Heat insulating material **14** is employed in the casting drum in Figure 2, and different varieties of refractory material may be employed as such heat insulating material. The recesses in the inner layer may also be air holes, and such air holes produce the same action and effects as heat insulating materials. The outer layer **15** in Figure 2 may also be formed of copper, or may be formed of metals other than copper, such as Ni or Cr and the like. The outer layer **15** may be formed by methods commonly

employed in the art, such as for example by metal spraying. The surface of the outer layer **15** is finished smoothly in the same fashion as was described for Figure 1.

[0022] In Figure 2, the heat insulating material possesses poorer heat transmission properties than Cu. Hence, the protrusions **11** of the inner layer **9** at which there is no heat insulating material transmit heat well, but the recesses **10** transmit heat poorly because of the presence of the heat insulating material. Hence the melt **1** that is in contact with the casting drums consists of the melt **11′** at positions that face the protrusions **11** which is rapidly cooled by the casting drums and in which solidification proceeds rapidly, and the melt **10′** at positions that face the recesses **10** which is slowly cooled by the casting drums and in which solidification proceeds slowly.

[0023] Thus the melt **1** that is in contact with the cooling drum of Figure 2 forms a melt in which the fine portion **11′** in which solidification proceeds rapidly and the fine portion **10′** in which solidification proceeds slowly are uniformly mixed and distributed. For this reason, the cooling drum in Figure 2 also prevents the development of cracking in the cast slab **5** for the same reasons as those described under Figure 1. Moreover, the problem of the formation of recesses and protrusions in the surface of the thin cast slab that have arisen hitherto is also overcome in the same manner as that described under Figure 1 because the outer surface of the outer layer **15** is smooth. Moreover, the outer layer in Figure 2 being formed of metal possesses considerably higher heat transmission properties than does the refractory material envisaged by JP6-67450, while such outer layer possesses sufficient heat transfer properties because the copper of the inner layer **9** is bonded to the metal of the outer layer **15** at the recesses **11** in the inner layer. For this reason, there is no necessity for the velocity of rotation of the cooling drums to be low, and the cooling drums can be operated with as high a level of efficiency as hitherto.

[0024] Figure 3 is a schematic explanatory drawing of a further cooling drum envisaged by the present invention, being a drawing of the same members as in Figure 1 (B). The casting drum in Figure 3 possesses on the surface thereof an inner layer **17** that is form of copper and an outer layer **16** that is so formed on the outer surface of the inner layer **17** as to cover the outer surface of the inner layer **17**; the outer layer **16** consists of metal in the interior of which fine heat insulating material **18** is uniformly distributed, the surface of the outer layer **16** is finished smoothly, and forms the outer surface of the casting drum, forming a casting drum of a twin drum type continuous casting machine.

[0025] In Figure 3, the metal that forms the outer layer **16** may be copper, or may also be a metal other than copper such as Ni or Cr and so forth. Moreover, various types of refractory material may be employed for the heat insulating material **18**. In Figure 3 the outer layer **16** which consists of metal in the

interior of which fine heat insulating material is uniformly distributed may be formed by for example disposing a woven cloth of heat insulating material upon the outer surface of the inner layer **17** and by spraying or plating metal from above onto such inner layer **17**. The heat insulating material **18** in Figure 3 may also be formed of air holes through the selection of the spraying conditions, and without the disposition of the woven cloth of heat insulating material, and in this case the air holes provide the same action and effect as the heat insulating material.

[0026] In Figure 3, the insulating material **18** possesses considerably poorer heat transfer properties than does the metal that forms the outer layer. Hence, those portions **19** in which there is no insulating material possess good heat transfer properties, but those portions **20** in which there is heat insulating material possess poor heat transfer properties. Hence the melt **1** that is in contact with the casting drums consists of the melt **19'** at positions that face **19** which is rapidly cooled by the casting drums and in which solidification proceeds rapidly, and the melt **20'** at positions that face **20** which is slowly cooled by the casting drums and in which solidification proceeds slowly.

[0027] Thus the melt **1** that comes into contact with the casting drum of Figure 3 forms a melt in which the fine portion **19'** in which solidification proceeds rapidly and the fine portion **20'** in which solidification proceeds slowly are uniformly mixed and distributed. For this reason, the cooling drum in Figure 3 also prevents the development of cracking in the cast slab **5** for the same reasons as those described under Figure 1. Moreover, the problem of the formation of recesses and protrusions in the surface of the thin cast slab that have arisen hitherto is also overcome in the same manner as that described under Figure 1 because the outer surface of the outer layer **16** is smooth. Moreover, the outer layer **16** in Figure 3 being formed of metal possesses considerably higher heat transmission properties than does the refractory material envisaged by JP6-67450, and for this reason, there is no necessity for the velocity of rotation of the cooling drums to be low, and the cooling drums can be operated with as high a level of efficiency as hitherto.

Practical embodiments

[0028] The four[1] types of surface layer of the casting drum listed in Table 1 were employed to manufacture Al-killed medium carbon thin cast slab with a slab thickness of 2 mm. All the casting drums were 400 mm in diameter and 350 mm in length, and the velocity of rotation of the casting drums was 40 m/min in all cases.

[0029] Drum A in Table 1 was a comparative example, possessing neither an inner layer nor an outer layer, but simply possessing a copper surface. Casting Drum A was finished smoothly to a surface roughness of not more than 10

[1] As in the Japanese text - Translator

μm. Drum B in Table 1 was a comparative example, possessing neither an inner layer nor an outer layer, but simply possessing a copper surface, but recesses and protrusions of 80 μm were formed on the surface of Drum B by shot blasting. Drum C in Table was a practical embodiment of the present invention, with an inner layer of copper upon which recesses and protrusions of 80 μm were formed by shot blasting, and on the outer surface of which an outer layer 30 μm in thickness of Ni was formed by plating, whereupon this surface was polished to a surface roughness of not more than 10 μm.

[0030] In Table 1, the Cast Slab Cracking column shows the results of visual inspections of the cast slab under a 15x loupe for cracking in the surface after the cast slab had been pickled, ◎ indicating (0 cm – 1 cm)/m^2, O indicating (over 1 cm – 10 cm)/m^2, Δ indicating (over 10 cm – 50 cm)/m^2 and X indicating (over 50 cm)/m^2. Moreover, in Table 1, the Cast Slab Roughness column shows the results of measurements with a surface roughness gauge of the cast slabs in the as cast state, ◎ indicating 0 μm – 8 μm, O indicating over 8 μ - 15 μm, Δ indicating over 15 μm – 30 μm, and X indicating over 30 μm.

Table 1

Drum	Drum surface roughness	Surface layer	Cast slab cracking	Cast slab roughness	Remarks
A	Not more than 10 μm	Single copper layer	X	◎	Comparative example
B	80 μm	Single copper layer	◎	X	Comparative example
C	Not more than 10 μm	80 μm roughness copper layer + 30 μm Ni outer layer	◎	◎	Practical embodiment

[0032] As can be seen from Table 1, cracking developed in the cast slab to the extent that the surface of Drum A was smooth. As can be seen from Table 1, the cast slab exhibited surface roughness because recesses and protrusions were formed in the surface of Drum B. As can be seen from Table 1, Drum C, being a practical embodiment of the present invention, enabled the manufacture of cast slab with a smooth surface and also prevented the formation of cracking.

Effects of the invention

[0033] When the casting drums envisaged by the present invention are employed in a twin drum type continuous casting machine, it is possible to manufacture thin cast slab with a smooth surface and also to prevent the development of cracking, without any loss in productivity of thin cast slab.

Simplified description of the drawings

Figure 1 is a schematic explanatory drawing of the surface of the first casting drum envisaged by the present invention.

Figure 2 is a schematic explanatory drawing of the surface of the second casting drum envisaged by the present invention.

Figure 3 is a schematic explanatory drawing of the surface of a further casting drum envisaged by the present invention.

Figure 4 is an explanatory drawing of a twin drum type continuous casting machine.

Explanation of symbols

1: Melt, **2 (2′)**: Casting drum, **3 (3′)**: Side weir, **4 (4′)**: Solidified shell, **5**: Thin cast slab, **6**: Direction of rotation of casting drum, **7**: Minimum interval between drums, **8**: Point of initiation of contact with melt, **9**: Copper inner layer, **10 (10-1, 10-2)**: Recess disposed on inner layer, **10′ (10′-1, 10′-2)**: Portion with slow progress of solidification, **11 (11-1, 11-2)**: Protrusion disposed on inner layer, **11′ (11′-1, 11′-2)**: Portion with rapid progress of solidification, **12**: Outer surface of outer layer, **13**: Outer layer, **14**: Heat insulating material, **15**: Outer layer, **16**: Outer layer, **17**: Copper inner layer, **18**: Heat insulating material, **19**: Portion without heat insulating material, **19′**: Portion with slow progress of solidification, **20**: Portion with heat insulating material, **20′**: Portion with rapid progress of solidification

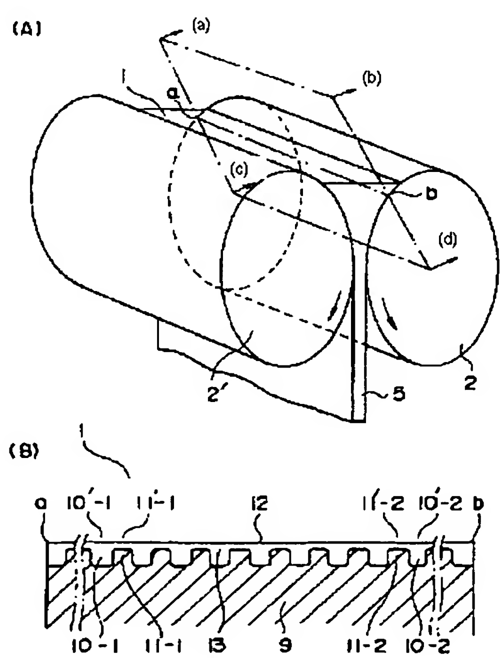


Figure 1

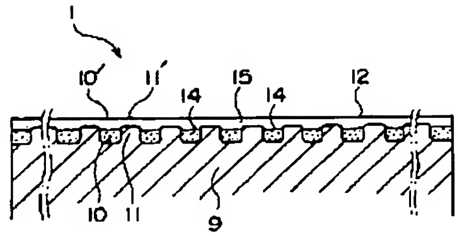


Figure 2

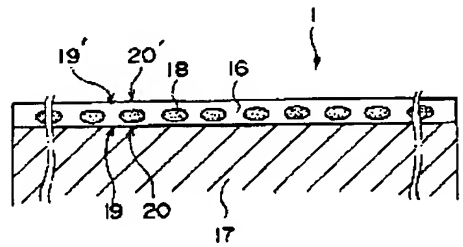


Figure 3

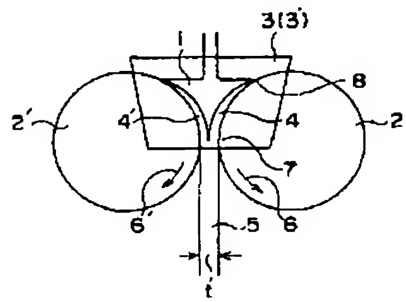


Figure 4